

Hydrology and fluvial geomorphology

Question	Answer	Marks
1(a)	<p>Fig. 1.1 is a photograph which shows the High Country Rivers, New Zealand.</p> <p>Name the type of river channel shown in Fig. 1.1.</p> <p>Braided</p>	1
1(b)	<p>Draw a cross-section of the river channel from X to Y shown in Fig. 1.1. Label the main features.</p> <p>The main river features which could be shown are:</p> <ul style="list-style-type: none"> • Multiple channels and islands/sand bars • The flat nature of the channel floor • Low vertical banks <p>2 marks for the cross-section, and 2 marks for the labelling.</p>	4
1(c)	<p>Suggest reasons for the formation of the channel type shown in Fig. 1.1.</p> <p>Explanation will be in terms of the factors causing braiding. The main ones are: high fluctuating discharges with a large, coarse sediment load, erodible banks, sudden change in gradient.</p> <p>1 mark for each simple explanation, 2 marks for a developed explanation up to a maximum of 5 marks.</p>	5

Atmosphere and weather

Question	Answer	Marks
2(a)	<p>Fig. 2.1 shows methane emissions, by sector, in the USA in 2018.</p> <p>Fig. 2.2 shows nitrous oxide emissions, by sector, in the USA in 2018.</p> <p>State the difference in percentage of methane emissions between energy and waste shown in Fig. 2.1.</p> <p>Candidates are required to interpret the pie section for both energy and waste, and then calculate the difference.</p> <p>Energy = 39%, Waste = 20% and therefore accurate difference = 19 (%).</p> <p>2 marks for accurate difference of 19 (% and working not required). 1 mark for less accurate difference of 17, 18, or 20 (% and working not required).</p>	2
2(b)	<p>Compare the emission sources for methane and nitrous oxide as shown in Fig. 2.1 and Fig. 2.2.</p> <p>The main points of comparison are:</p> <p>For methane (Fig. 2.1): energy (39%) and agriculture (39%) are the greatest, followed by waste (20%) with forestry and industry almost negligible (2% and 0%).</p> <p>For nitrous oxide (Fig. 2.2): overwhelmingly agriculture (80%), followed by energy (10%) with a small proportion from industry (6%) with forestry and waste negligible (2% and 2%).</p> <p>Four relevant points for 4 marks. Data/figures required for full marks.</p>	4
2(c)	<p>Explain the role of greenhouse gases in global warming.</p> <p>The explanation needs to focus on:</p> <ul style="list-style-type: none"> • The types of greenhouse gases (carbon dioxide, methane, water vapour, ozone, nitrous oxides, CFCs) • How they allow incoming short-wave radiation to pass through the atmosphere • How they trap outgoing longwave radiation • Leading to an increase in temperature and global warming <p>1 mark for each simple explanation, 2 marks for a developed explanation up to the maximum.</p>	4

Rocks and weathering

Question	Answer	Marks
3(a)(i)	<p>Fig. 3.1 shows types of weathering, rainfall and temperature.</p> <p>State the weathering occurring at: A</p> <p>Moderate chemical weathering/very slight physical weathering on its own or in combination.</p>	1
3(a)(ii)	<p>State the weathering occurring at: B.</p> <p>Slight chemical weathering/very slight physical, but not slight physical on its own.</p> <p>Very slight (or similar qualification) weathering on its own acceptable.</p>	1
3(b)	<p>Calculate the range of mean annual rainfall for 'moderate chemical weathering with slight physical weathering'. Show your working.</p> <p>500 for the lower rainfall amount with 1600 to 1700 for the upper rainfall amount. The correct answer (1100–1200) for the extra mark. The units must appear somewhere for full credit.</p>	2
3(c)	<p>Explain how rainfall influences the type of weathering.</p> <p>Many weathering processes rely on water, especially chemical weathering, e.g. carbonation, hydrolysis, and solution. Some physical weathering also relies on water, such as freeze-thaw and salt crystallisation, as does biological weathering. A detailed explanation of a variety of chemical weathering processes can get maximum marks.</p> <p>Type of weathering associated with a simple explanation, 1 mark.</p> <p>1 mark for each simple explanation, 2 marks for each developed explanation, or 3 marks for each well developed explanation to a maximum of 6 marks.</p>	6

Section B

Answer **one** question from this section. All questions are worth 30 marks.

Hydrology and fluvial geomorphology

Question	Answer	Marks
4(a)(i)	<p>Describe the conditions which lead to overland flow on slopes.</p> <p>The main points to be considered are:</p> <ul style="list-style-type: none"> • High input of rainfall on slopes or sudden melting of snow • Impermeability of the ground surface • Antecedent moisture/saturated ground • Steep slopes • Low level of interception by vegetation <p>Low infiltration without qualification is not creditable.</p> <p>1 mark for each point.</p>	3
4(a)(ii)	<p>Explain how the shape of a drainage basin affects the shape of a storm hydrograph.</p> <p>The main points are:</p> <ul style="list-style-type: none"> • The shape of the storm hydrograph is governed by the amount and speed of water reaching the river channel • A circular drainage basin generally possesses tributaries that converge on the main channel quickly; development – producing a rapid rise in discharge in the main channel which is reflected on the hydrograph (steep rising limb, high peak discharge) • An elongated drainage basin possesses tributaries that join at separate points along the main channel; development – producing a more measured hydrograph response (less steep rising limb lower peak discharge) • There may be reference to other more complicated drainage basin shapes <p>Diagram could be used and should be credited if relevant, clear and correct.</p> <p>1 mark for each simple explanation, 2 marks for a developed explanation up to the maximum.</p>	4

Question	Answer	Marks
4(b)	<p>Explain how the Hjulström curve is used to explain erosion and deposition in a river channel.</p> <p>The Hjulström curve shows the relationship between water velocity and sediment size and erosion (entrainment), transport and deposition. It therefore shows the critical velocities at which erosion and deposition may occur in river channels. The shape of the curve also shows that the finer particles need higher velocities for entrainment because clay particles resist entrainment due to their cohesion. Candidates need to refer to relevant characteristics of the particles, such as weight and shape for a Level 3 mark.</p> <p>Award marks based on the quality of explanation and breadth of the response using the marking levels below.</p> <p>Level 3 (6–8) Response clearly explains how the Hjulström curve is used to explain erosion and deposition in a river channel. Response is well founded in detailed knowledge and strong conceptual understanding of the topic. Examples used are appropriate and integrated effectively into the response.</p> <p>Level 2 (3–5) Response explains how the Hjulström curve is used to explain erosion and deposition in a river channel. Response develops on a largely secure base of knowledge and understanding. Examples may lack detail or development.</p> <p>Level 1 (1–2) Response describes how the Hjulström curve is used to explain erosion and deposition in a river channel. Knowledge is basic and understanding may be inaccurate. Examples are in name only or lacking entirely.</p> <p>Level 0 (0) No creditable response.</p>	8

4 (c) With the aid of examples, assess the view that the amount of rainfall is the most important factor in causing a river to flood. (15 marks)

The overall command word is '**assess**'. Candidates are required to evaluate the relative importance of the *amount of rainfall* compared to other factors (both physical and human) in causing a river to flood. A strong response will recognise that while the amount of precipitation is the primary input or climatic cause, the magnitude and frequency of flooding are often determined by flood-intensifying conditions related to the drainage basin's characteristics.

Responses must use appropriate examples integrated effectively into the argument.

1. Argument for Rainfall Amount/Type as the Most Important Factor

- **Primary Input:** Precipitation (including rainfall, snow, hail, etc.) is the main input into the drainage basin system. Without sufficient input, flooding cannot occur.
- **High Amounts:** High rainfall amounts or prolonged rainfall can saturate the ground, leading to increased runoff and resulting in high river discharge.
- **Specific Types:** Prolonged, heavy **monsoon rains** (e.g., Bangladesh/India, where up to 70 per cent of annual rainfall occurs during the summer monsoon) are the primary causes of flooding in certain regions.

- **Snowmelt:** Large volumes of water entering the system rapidly due to **sudden, rapid melting of snow** or glaciers can cause flooding and high peak flows.

2. Argument Against Rainfall Amount being the Only/Most Important Factor (Other Physical Factors)

Candidates should evaluate the role of rainfall *intensity* versus total *amount*, and compare these factors to basin characteristics, noting that these factors often determine the severity of the flood or the basin's response.

- **Intensity vs. Amount:** Highly intensive rainfall is likely to produce **overland flow** and a steep rising limb/high peak flow, even if the total volume is not exceptional. This bypasses infiltration capacity.
- **Antecedent Moisture:** If the ground is **saturated or near saturated** (high antecedent moisture), rainfall (even moderate amounts) will quickly produce overland flow, leading to a high peak flow and short lag time, increasing flood risk.
- **Topography/Relief: Steeper slopes** create more overland flow, shorter time lags, and higher peak flows.
- **Geology and Soil: Impermeable rocks** (e.g., granite, clay) or surfaces cause more water to flow overland (surface runoff), resulting in greater peak flows and shorter lag times, increasing flood likelihood.
- **Basin Shape and Size: Circular basins** respond more quickly than linear ones (flashy hydrographs), meaning the *same amount* of rain could cause a flood in one shape but not another.
- **Coastal/Tidal factors:** Flooding can be intensified by **high tides or coastal storm surges**, independent of the amount of upstream rainfall.

3. Argument Against Rainfall Amount being the Only/Most Important Factor (Human Factors)

Human-induced flood-intensifying conditions significantly increase the magnitude and frequency of floods.

- **Urbanisation:** Creation of **highly impermeable surfaces** (concrete, roads). This reduces infiltration and increases surface runoff. Also, dense drainage networks increase drainage density, rapidly carrying water to the river.
- **Deforestation/Land Use:** Reduction of vegetation cover leads to reduced interception and evapotranspiration, increasing surface runoff and decreasing the lag time.
- **Channel Modification/Hard Engineering:** River engineering (e.g., channel straightening or building levees) is intended to prevent flooding but can sometimes **aggravate flood problems downstream** or lead to catastrophic failure if breached, such as the poorly built levees during the Mississippi flood of 1993.
- **Floodplain Development:** Developing on natural floodplains increases the risk of damage.

4. Conclusion / Assessment

A thorough assessment will reach a justified conclusion, arguing that while rainfall (amount or intensity) is generally the necessary triggering mechanism (climatic cause), other factors (both physical, like antecedent moisture, and human, like urbanisation) determine the **vulnerability, magnitude, and speed** of the flood event. Therefore, in many highly modified or vulnerable drainage basins (e.g., urbanised areas, deforested steep slopes, or low-lying areas like Bangladesh), the influence of basin characteristics or human activity may be judged *more important* in converting a high flow event into a catastrophic flood.

Marking Rubric (15 Marks)

When marking, priority should be given to the **quality of the assessment and the effectiveness of examples**. Responses without examples will generally be limited to the middle of Level 2 (6 marks).

Level Marks Description

4	12–15	The response thoroughly assesses the view that the amount of rainfall is the most important factor in causing a river to flood. The argument is well-balanced , clearly evaluating rainfall against a comprehensive range of other physical and human factors (e.g., antecedent moisture, permeability, urbanisation). The response is well-founded in detailed knowledge and demonstrates a strong conceptual understanding of how the drainage basin system responds to inputs. Examples are appropriate and integrated effectively throughout the response to support the assessment. A clear and justified conclusion is provided.
3	8–11	The response addresses the question but the assessment may be unbalanced (e.g., focusing heavily on rainfall while giving less depth to comparison factors, or vice versa). The response develops on a largely secure base of knowledge and understanding . Examples are used, but they may lack detail or full development in supporting the evaluative points. A reasonable attempt at a conclusion is made.
2	4–7	The response shows a general knowledge and understanding of the causes of flooding. The response is mainly descriptive or explanatory , listing several causes but attempting limited evaluation of rainfall's relative importance. Knowledge may be superficial or conceptual understanding partial. Examples are limited or generic; a general response without the use of example(s) will not get above the middle of Level 2 (6 marks). Some concluding remarks may be present.
1	1–3	The response makes a basic attempt to address the question but lacks focus or relevance. Knowledge is basic , and understanding is poor or inaccurate. The response is mostly descriptive and fails to provide a convincing conclusion or assessment. Examples are likely to be absent or incorrect.
0	0	No creditable response provided.

Atmosphere and weather

Question	Answer	Marks
5(a)(i)	<p>Describe how the type of surface affects the albedo rate.</p> <p>The following factors could be considered:</p> <ul style="list-style-type: none"> • lighter coloured surfaces have higher albedo rates (1) such as ice and snow/accurate percentages (DEV) • more solar radiation is reflected off lighter surfaces (1) • darker coloured surfaces have lower albedo rates (1) such as tarmac, ploughed fields and coniferous forests/accurate percentages (DEV) • more solar radiation is absorbed by darker surfaces (1) <p>1 mark for each simple description, 2 marks for a developed description, up to max. 2.</p>	4
5(a)(ii)	<p>Explain <u>one</u> way the incoming (shortwave) radiation is reflected back into the atmosphere before it reaches the Earth's surface.</p> <p>Ways could include:</p> <ul style="list-style-type: none"> • clouds/water droplets/ice crystals • clouds normally have a higher albedo than the surrounding atmosphere • scattered/bounced back into the atmosphere <p>1 mark for a simple explanatory point, 2 marks for a developed explanation and 3 marks for a well-developed explanation.</p>	3

Question	Answer	Marks
5(b)	<p>Explain the different causes of precipitation.</p> <p>The four main causes are:</p> <ul style="list-style-type: none"> • convectional • orographic • frontal • radiation cooling <p>The candidate should describe the process of the air being forced to rise due to convection / relief / front and then the processes by which precipitation is formed (cooling, condensing, forming of water vapour and droplets).</p> <p>For the first three causes, the following factors are relevant:</p> <ul style="list-style-type: none"> • the mechanism that forces air to rise • the air on rising then cools • and if it cools (to below dew point), condensation occurs • water droplets may coalesce to produce rain <p>Award marks based on the quality of explanation and breadth of the response using the marking levels below.</p> <p>Level 3 (6–8) Response clearly explains the different causes of precipitation. Response is well founded in detailed knowledge and strong conceptual understanding of the topic. Examples used are appropriate and integrated effectively into the response.</p> <p>Level 2 (3–5) Response explains the different causes of precipitation. Response develops on a largely secure base of knowledge and understanding. Examples may lack detail or development.</p> <p>Level 1 (1–2) Response describes the different causes of precipitation. Knowledge is basic and understanding may be inaccurate. Examples are in name only or lacking entirely.</p> <p>Level 0 (0) No creditable response.</p>	8

Question	Answer	Marks
5(c)	<p>'Incoming solar radiation is the most important factor in determining the global energy budget.'</p> <p>With the aid of examples, how far do you agree with this statement?</p> <p>Global energy budget is the balance between incoming radiation (shortwave) and outgoing radiation (longwave).</p> <p>It can be argued that incoming solar radiation is the most important factor, as without this, the budget would not exist. Incoming solar radiation is affected by absorption, re-radiation, reflection, scattering, etc.</p> <p>Credit can also be given to discussion on:</p> <ul style="list-style-type: none"> • latitudinal pattern of radiation (excesses and deficits) • atmospheric transfers – wind belts and ocean currents • seasonal variation in temperature, pressure and wind belts – influence of latitude, land/sea distribution and ocean currents <p>Award marks based on the quality of the response using the marking levels below.</p> <p>Level 4 (12–15) Response thoroughly assesses the extent to which incoming solar radiation is the most important factor in determining the global energy budget. Examples used are appropriate and integrated effectively into the response. Response is well founded in detailed knowledge and strong conceptual understanding of the topic.</p> <p>Level 3 (8–11) Response assesses the extent to which incoming solar radiation is the most important factor in determining the global energy budget but may be unbalanced. Examples may lack detail or development. Response develops on a largely secure base of knowledge and understanding.</p> <p>Level 2 (4–7) Response shows general knowledge and understanding of the extent to which incoming solar radiation is the most important factor in determining the global energy budget. Response is mainly descriptive or explanatory with limited use of examples and understanding of the topic may be partial or inaccurate. Some concluding remarks. General responses without the use of example(s) will not get above the middle of Level 2 (6 marks).</p> <p>Level 1 (1–3) Response may broadly discuss incoming solar radiation and the global energy budget but does not address the question and does not come to a convincing conclusion. Response is descriptive, knowledge is basic and understanding is poor.</p> <p>Level 0 (0) No creditable response.</p>	15

Rocks and weathering

Question	Answer	Marks
6(a)(i)	<p>Define the terms <i>rainsplash</i> and <i>rills</i>.</p> <p>Rainsplash is when precipitation hits bare soil (1) which dislodges soil particles (1).</p> <p>Rills are (small, shallow) channels (1) cut by water flowing over soils (1).</p>	4
6(a)(ii)	<p>Briefly explain how afforestation can reduce mass movement on a slope.</p> <p>Afforestation is when trees are planted on slopes. It is often done in an attempt to stabilise unstable or potentially unstable slopes.</p> <ul style="list-style-type: none"> • Trees will intercept and absorb water, which reduces water in soils, decreasing the likelihood of high pore water pressure and therefore a reduction in shear strength. • Reducing the amount of water on slopes and in soils • Roots will bind soil material, increasing shear strength and helping to prevent the effects of gravity leading to mass movement such as landslides or slumping. This may reduce shallow landslides but have little effect on large, deep-seated landslides. • Afforestation may help to reduce the overall water load and content of the rocks and sediments in an area, which might reduce the weight of the material and decrease the effects of gravity that lead to mass movements. However, this may be counterbalanced by the weight of the trees. • If the slope has exposed rock surfaces, then trees can slow down forms of physical weathering which can lead to mass movement. <p>1 mark for each explanatory point.</p>	3

6 (b) Explain how rock type and structure influence the type and rate of weathering. [8]

The type and rate of weathering (the decomposition and disintegration of rocks *in situ*) are significantly influenced by the geological characteristics of the exposed rock. These influences are categorised by the rock's chemical composition (rock type) and its physical characteristics (rock structure).

1. Influence of Rock Type (Chemical Composition)

The mineral composition of a rock determines its susceptibility to chemical breakdown and thus dictates the prevailing type of chemical weathering and its rate.

Chemical Weathering Type: Limestone consists of calcium carbonate, which makes it highly susceptible to carbonation-solution. In this process, rainfall combined with dissolved carbon dioxide forms a weak carbonic acid, which reacts with the calcium carbonate to produce soluble calcium bicarbonate that is then removed by percolating water.

Hydrolysis: Granite is prone to hydrolysis due to the presence of the mineral feldspar. This chemical process involves water (often slightly acidic) reacting with the feldspar to produce kaolinite (china clay), which chemically alters and weakens the rock.

Oxidation In sedimentary rocks, the nature of the cement is critical; iron-oxide-based cements are prone to oxidation (breakdown by oxygen and water). Conversely, rocks formed of resistant minerals, such as quartz, will resist weathering processes, thereby reducing the rate

Physical Weathering Rate: The mineralogy can also influence the rate of physical weathering, such as the differential thermal conductivities of minerals in granite, which make it susceptible to disintegration or **insolation weathering**.

2. Influence of Rock Structure (Joints and Porosity)

Rock structure refers to physical characteristics like jointing, bedding planes, porosity, and permeability, which largely control the movement of water, the key medium for chemical weathering:

Joints and Penetration (Rate): Rock structure provides lines of weakness that are exploited by weathering. Rocks with **joints and bedding planes** are more vulnerable because water can penetrate them easily.

Chemical Weathering (Rate): Joints exert a strong control on water movement, facilitating solution and chemical alteration within the rock mass. The solution of limestone, for instance, is greater along the joints (called **grikes**).

Physical Weathering (Type): Joints and cracks allow water to enter and freeze in cold environments, leading to the process of freeze-thaw weathering, where the expansion of water exerts pressure and breaks the rock. Similarly, the presence of these weaknesses allows vegetation roots to grow and exert pressure, leading to physical weathering (**root action**).

Porosity and Permeability (Rate): The rate of disintegration is closely related to a rock's porosity (capacity to hold water) and permeability (ability to transmit water through joints and fissures). Coarse-grained rocks often weather quickly due to their large void space and high permeability, allowing greater access for water.

Question	Answer	Marks
6(c)	<p>With the aid of examples, assess the extent to which subduction is involved in the formation of tectonic landforms.</p> <p>Candidates are free to develop their own approach to the question and responses will vary depending on the approach chosen. Whichever approach is chosen, essays which address the question and support their argument with relevant examples will be credited. There may be detailed consideration of a case study/one or more examples, or a broadly conceived response, drawing on several examples to illustrate the factors involved.</p> <p>The main tectonic landforms are volcanoes, fold mountains, ocean trenches, volcanic island arcs, mid-ocean ridges and fault valleys. Subduction is when one oceanic plate is forced below either another oceanic plate or continental plate. Landforms associated with subduction are volcanoes, fold mountains, ocean trenches and volcanic island arcs depending on which plates are involved. Some volcanoes are associated with sea floor spreading or mantle plumes at hot spots e.g. Hawaii. Some fold mountains are associated with collision between two continental plates with no major subduction and melting of the crusts, therefore no volcanic action. Mid-ocean ridges are the result of magma rising at sea floor spreading sites. Fault valleys are the result of plates moving apart e.g. East African Rift Valley. These considerations will form the basis of the assessment.</p> <p>Award marks based on the quality of the response using the marking levels below.</p> <p>Level 4 (12–15) Response thoroughly discusses the extent to which subduction determines the formation of tectonic landforms. Examples used are appropriate and integrated effectively into the response. Response is well founded in detailed knowledge and strong conceptual understanding of the topic.</p> <p>Level 3 (8–11) Response discusses the extent to which subduction determines the formation of tectonic landforms but may be unbalanced. Examples may lack detail or development. Response develops on a largely secure base of knowledge and understanding.</p> <p>Level 2 (4–7) Response shows general knowledge and understanding of the extent to which subduction determines the formation of tectonic landforms. Response is mainly descriptive or explanatory with limited use of examples and understanding of the topic may be partial or inaccurate. Some concluding remarks. General responses without the use of example(s) will not get above the middle of Level 2 (6 marks).</p>	15